DUGAN

An Investigation of Electric Railway Rail Bonds

Railway Electrical Engineering

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AN INVESTIGATION OF ELECTRIC RAILWAY RAIL BONDS

BY

Charles Bedard Dugan

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

CHARLES BEDARD DUGAN

ENTITLED AN INVESTIGATION OF ELECTRIC RAILWAY RAIL BONDS

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Railway Electrical Engineering

Edward C. Schmidt & Edgar J. Wenger
Instructor in Charge.

APPROVED: W. F. M. Goss

HEAD OF DEPARTMENT OF Railway Engineering

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AN INVESTIGATION OF ELECTRIC RAILWAY RAIL BONDS.

Due to the enormous growth, during the past few years, of electricity as a means of traction, the details of electrically operated roads, which at first appeared to be of minor importance, demand careful consideration in their present day development. Engineers have paid close attention to steam economy, and the results of their work are shown in the magnificent power houses, models of modern ideas, built through-out the United States, Great Britain and France. Yet recent tests made at Paris show that a large portion of saving effected by modern compound and triple expansion engines can be wasted in overcoming the resistance of poor contacts between the various sections of the conductors.

A high authority in the electric railway field has stated that an extra resistance of one ohm in a circuit in which one hundred electric cars are operated, will cause the loss of an amount of power sufficient to operate double that number. Electric railway engineers recognize this fact as far as the trolley wire feeders are concerned, whether these are operated on poles or in conduits, since the unbroken lengths of these conductots are made of as long sections as possible, and the joints are always carefully soldered. But the same care is not ordinarily exercised in regard to the joints in the conductors within the power house, or in the rail return circuit. There are usually twelve to sixteen

breaks in the power house circuit between each dynamo and the bus bars; four at the main switch; two at the dynamo terminals; one or two at the equalizing bus bar, two or four at the terminals of the fuse blocks or circuit breakers; two at the ammeter shunt; and two at the bus bars.

Altho these contacts are generally made of pure copper and machined to a careful fit with ample section for the maximum current, instances are on record in which nearly five per cent of the energy developed by the dynamo was wasted in merely overcoming the resistance of these power house contacts. These losses are hard to detect, since, owing to the presence of the steam engines and piping in the dynamo room, the temperature of all exposed metal work, including conductors, is very high. Therefore, a conductor, heated on account of a poor contact, cannot be distinguished from a conductor heated by the proximity of steam pipes, without the use of a millivoltmeter, having a very low reading scale.

In the rail return circuit, the losses are still more difficult to detect. Here the rails ordinarily used have a section of from seven to nine or ten square inches, which is equivelant to from seven eighths to one and one half square inches of copper section. These conductors are in length from thirty to thirty three feet, and the fish plates or rail joints, as ordinarily applied, are not effective conductors, on account of the coating of iron oxide, which is a good insulator, between the contact surfaces. This coating of iron oxide will follow a steel surface even under the head of a steel rivet, applied in a boiler plate by

hydraulic pressure.

The selection of bonding for a given road depends both upon the current carrying capacity and the contact resistance desired, and is determined by the class of service involved and the conditions met with.

Double bonding is resorted to in many instances in order to insure a path of good conductivity in case of the failure of a single bond. Where double bonding is not required to provide the additional current carrying capacity in order to keep the temperature rise within reasonable limits, it is better engineering to install a single bond of sufficient capacity, and to maintain this bonding in good condition. Double bonding is open to the objection that one of the two bonds at the joint will give imperfect contact and be practically useless, and such a method of installation usually results in operating the road with practically single bonding throughout.

Single bonding on interurban roads, where the service is infrequent and the current demands do not exceed momentarily one thousand amperes, is advised by prominent engineers, provided the rails are frequently cross bonded and all the joints are regularly inspected and maintained in good condition.

The heating of bonds will determine the size and number of bonds to be used on roads over which there is a large volume of traffic, and where the moving units require a large kilowatt input, such as trains hauled by locomotives.

The following table shows the relation existing between the rise in temerpature and the current flowing in a 9" - 4/0 bond.

Current in amperes	500	1000	1500	2000	2500
Temparature rise in degrees C.	10	35	78	135	210

The table of heating constants applies only to bonds exposed to the air and not covered by fish plates, for in the latter case the heating will be somewhat increased, The values given in the table apply only to bonds maintaining good contact with the rail. As one of the rails composing the return circuit may become useless owing to the failure of one or more bonds, each rail must or should be bonded with the prospect of carrying the full return current. Moreover, as the heating of the bond varies as the square of the current value, and extremes in temperature are to avoided owing to the unequal expansion of copper bonds,and rail, it is desirable that the greatest conservatism be used in the selection of bonds for a given service. This is especially true where soldered bonds are concerned, but brazed and welded bonds will stand higher temperatures without danger of coming off.

One of the usual methodsof connecting rails, electrically, is to drill one or more holes through the end of each rail, and insert the terminal of a copper bond leading across the joint. Figs. 10 - 11 - 12. This terminal is expanded into the hole by various mechanical means, either by driving a steel wedge, or ball, or conical plug, or by expanding the solid copper lug with a screw or hydraulic pressure. These contacts, if carefully made, may at first prove fairly effective, but the different ratios

of expansion of steel and copper through the variations of temperature, soon result in decreasing the diameter of the copper plug and increasing its length, thus admitting moisture which will oxidize the contact surfaces. At first thought this may seem impossible, but the fact has been established by experiment. When the temperature rises the copper plug in the steel plate must expand at a greater ratio than the steel; the force of the copper's expansion is not sufficient to increase the diameter of the hole in the steel; therefore its entire expansion takes place in a line parallell with the axis of the hole. When the joint cools there is nothing to prevent the copper from contracting in all directions, The plug is therefore of less diameter and greater length than before it was heated. The tests made by the " Laboratoire d' Electricité" show that contacts of this kind were very far from being perfect, even when first applied.

Expanded terminal bonds comprise all those which depend upon expanding a soft copper core into contact with the rail, through a hole in the web or flange. The size of the hole in the rail varies with the capacity and type of the bond used, ranging from five eighths of an inch to one inch in diameter. There are two general types of expanded terminal bonds.

The steel core bond comprises a soft steel center inserted in a copper head, and so designed that, when placed in the rail and pressure applied, the expansion of the steel core center, or its increase in diameter, will

force the copper head into close contact with the rail.

The second type of expanded terminal bond comprises two solid copper heads or terminals into which is forged or welded a laminated copper conductor joining the two. Fig.9. When the bond is in place and pressure applied, the soft copper head is expanded into close contact with the rail. Bonds of the expanded terminal type are designed for use either beneath the fish plate or on the outside of the ball of the rail, or are made long enough to span the joint completely. Where the conductor joining the terminals is of considerable length, as in cross bonding, it is sometimes made of solid copper wire, but a stranded or laminated conductor is absolutely necessary where the bond is short and must conform with the rail deflections at the joints.

Soldered bonds, shown in figs. 5 - 16 - 22 - 23, comprise a laminated copper conductor terminating in two solid heads, which latter are joined to the rail by soldering, brazing or welding. The bond is attached to the outside of the ball of the rail, to the web of the rail under the joint plates, to the outside of the plate end of the plate and rail or to the bottom flange of the rail, underneath the the joint. In two of these cases the bond is open to view, which greatly facilitates inspection and renewal, but also makes the bond liable to theft, a great disadvantage in such a type of bond. It is difficult to obtain a contact by soldering, which will withstand the constant vibration and shocksto which the joint is subjected, but the welded and brazed bonds appear to be more free from this objection. Where good

permanent contact can be secured, the accessibility and cheapness of this method recommends it. Another point, however-namely, the life of the bond - enters into the discussion of the advisibility of this method of bond application. The General Electric Company made some interesting tests on bonds, a comparison being made between the life of a bond applied without heat and a bond which was electrically brazed to a rail. Two bonds, a stramded 4/0 -8-1/2" brazed bond and a standard 4/0 7/8" solid terminal ribbon bond 10" long, were assembled on two pieces of rail and then operated in a shaper in such a way as to simulate in the bonds the vibration which would result from a movement of 1/4" between the rail ends. In the case of the bond where the intense heat of brazing was used, the ribbons began to break near the welding point, after nine hours of operation representing 243000 complete vibrations. A second sample, where a little more heat was used, began to break after three hours operation at the same speed. When the stranded 10" bond was used, it was subjected to a motion equivalent to 3/8" movement between the rail ends. The first ribbon broke in 165 hours representing 4 1/2 million vibrations. The second ribbon broke in 350 hours or 9 1/2 million vibrations. After that the remaining ribbons broke in rapid succession. This would indicate that in heating the copper for brazing, it becomes brittle or crystaline in structure. The life of bonds therefore, depends upon the manner of installation and the service conditions encountered.

Amalgam bonds have been used with some success, the most modern type being a plastic alloy or putty like compound which makes contact between the rail and the splice bar or angle plate, and which is held in place by a flexible elastic cork case. Figs. 20 - 21. The current passes from one rail through one plug to the angle plate, and then through the second plug from the plate to the next rail. This type of bonding is easy to apply and is useful where a concealed bond is desired.

Welded joints, in general, give the greatest satisfaction where it becomes necessary to bond the rail to its full current carrying capacity. Welding is obtained by three methods, a cast, electric, and thermit weld.

Cast welding is secured by pouring the metal into a mold surrounding the rail joint, which latter has been thoroughly cleaned for the purpose. Such joints will have no expansion, are somewhat liable to crack, and are best suited for use in city streets, where the track is held rigidly in place by the pavement.

Thermit welding is obtained in a somewhat like manner except that a relatively small amount of finely divided aluminum and iron oxide form the liquid steel by rapid combustion and fusing, immediately over the prepared rail ends.

Electric welding at the rail joint is perhaps best secured by welding a steel strap to each rail, the joint not being continuous between the strap and the rail, but

maintained at one or two points of contact. This method has been adopted by the Loraine Steel Co.

All forms of welding are necessarily somewhat expensive, and are not well adapted to the requirements of interurban roads using T rails laid on ties in the open, on account of the inability of such joints to allow for the rail expansion and contraction.

A great many small roads, where the the traffic is light and well distributed, use the simple and inexpensive method of bonding by jumping from one rail to the next outside of the joint, and either tapping the solid copper conductor directly to the web of the rail and riveting the end, or drawing the conductor into close contact with the rail web by means of a soft metal channel pin. Both of these latter methods, however, give very little surface area, the bonds are very liable to theft, since they are exposed, and are very short lived, due to the ease with which moisture can work in and destroy the surface contact by oxidation.

In conjunction with the written work on this thesis a series of tests was carried on to determine the voltage drop across the characteristic types of bonds when properly and carefully installed, and to ascertain the relative rise in temperature for the bonds carrying a given constant current, for an equal time interval. The method of testing is shown in Fig. 1.

Standard T rail was used, sawed into sections

sixteen inches long. These pieces were drilled similarly to the end of a standard rail, and then bolted together, in pairs with the standard fish plates. The completed joints were then single bonded with the typical bonds in general use, care being taken that the contacts between the bond and the rail were as nearly perfect as possible. A one inch hole, one inch deep, was drilled into the top of the rail ball at each end of the completed joint, outside of the plates. This hole was used as a mercury cup, in which to hang the positive and negative wires, and offered the best possible low resistance contact, while the bonded joint was under test.

The current was obtained from a large capacity storage battery, which furnished a constant flow. The rail joint under test, in series with an ammeter, was connected across the battery terminals, the initial temperature read and the conditions then constantly maintained for a given time interval. The final temperature was then observed and the millivolts drop across the joint obtained by inserting in the mercury cup in the rail end, the leads from a voltmeter, and observing the deflection of the instrument. This order was carried out for all of the joints and the process thăn repeated with a different current flow, the change being accomplished by placing a resistance in series with the bonded joint under test.

The accompanying table shows the results of the tests, and furnishes an easy means for a comparison of the

performance of the several bonds represented.

Type of Bond	I	E.M.F. Battery Term'ls	Drop over joint Millivolts	Temp.rise C	Duration of test
Plastic Rail	918	.70	115	3.0	20 min.
Bond 4/0	825	.67	76	4.0	25 "
70# standard	639	.61	69	2.0	20 "
T rail					
Semi Plastic	255	.41	73	0.0	20 "
Plug 4/0,	800	.71	71	1.0	25 "
70# standard	600	.60	70	0.5	20 "
T rail					
Type "C"Form	1320	.67	110	2.0	20 "
4/0, Thomas	630	1.10	127	7.0	25 "
soldered					
Type "BB",4/0	830	.71			
Shawmut	825	.67	118	5.5	20 "
Soldered			110	9.0	25 "
Type C.S.2	673	.65	184	3.0	20 "
4/0. Am.	580	.62	91	8.0	25 "
Wire&Steel					
Co.Com-					
pressed					
Term'l					
2/0 Solid	520	.50	160	124.50	20 "
Copper Jum-	580	.62	176	138.0	25 "
per.Channel					
Pinned to Web					
No Bond	355	.71	505	13.0	20 "
Joint with	630	1.10	585	28.0	25 "
Plates					
only					

The following tables show the average first cost of a general type of bonding, compiled from data collected by three electric railway companies operating in the state of Illinois, over distances of about fifty miles.

Type of bond installed--------	Compressed Terminal Ribbon Bond
Class of work----- -----------	Construction
Time of year-----------------	December and January
Condition of traffic----------	Work trains at irregular intervals
Condition of track------------	No balast, - ties 1/2 spaced
Type of joint-----------------	1/2 bolted, unspiked..
Method of bond installation--	Compressed in hole in rail-web
Number of men in gang---------	15 - 19
Rateof payment of men ---------	10 hours per day at 17 1/2¢ per hour.
Men in charge-----------------	One foreman
Salary of superintendence--- -	$60.00 per month
Cost of bond------------------	53¢ each in lots of 1000
Cost of bond installation-----	25¢ - 30¢

Remarks:-- Above cost of installation is alittle above the average price which is generally obtained. The rail was drilled on the job with a Ludlow Portable Drill using water as a lubricant on the bits. The increase in price was due to the conflicting weather conditions.

The joints were fully bolted and spiked before leaving.

Bonds manufactured by the General Electric Company.

Type of bond installed -------Compressed Terminal Ribbon Bond

Class of work -------------Maintenance

Time of year --------------- September

Conditions of traffic--------- Semi-hourly service

Conditions of track ---------- Fully ballasted road way

Type of joint --------------- Continuous

Condition of joint -----------Spiked and full-bolted

Method of bond installation-- Expanded in hole in rail-web

Number of men in gang---------Three

Rate of payment of men-------$1.50 for a ten hour day.

Men in charge----------------- One foreman

Salary of superintendence----- $50.00 per month.

Cost of bond ---------------- 53¢ each, in lots of 1000

Cost of bond installation----- 35¢ - average.

Remarks:-- The above high cost of installation per bond is due to the fact that the work was maintenance and the joints therefore scattered - three hundred joints in forty miles of track. The time given to the men per day also included time consumed in going and coming from work.

Type of bond installed-------- Compressed Terminal Bond

Class of work----------------- Construction

Time of year----------------- November

Condition of traffic--------- Gravel train at irregular intervals

Conditions of track -----------Down in dirt - covered with gravel.

Type of joint -------------- Continuous

Condition of joint------------2 bolts - unspiked

Method of bond installation --Expanded in hole in rail web.

Number of men in gang---------17

Rate of payment for men------ 10 hours per day at 17 1/2¢ per hour.

Men in charge-----------------One foreman

Salary of superintendence-----$60.00 per month

Cost of bond------------------53¢ each in lots of 1000

Cost of bond installation-----35¢ average

Remarks:-- This cost of installation, which shows a maximum for the type of bonding, is due to the inability to freely move the 750 pound drill. This drill was mounted on small wheels gauged for standard track, but since the ballast was so heaped between the rails, the drill and carriage had to be dragged from joint to joint. With properly ballasted track, that is, gravel under the ties and track up and clear, the cost of installation can be reduced to from 13¢ to 17¢, which price may be considered a minimum. A fair average for new work is 22¢, as a cost of installation per bond per joint. In rebonding old work the cost is very indefinite, due to the great variety of conditions met with.

Type of bond installed ---------Compressed Terminal Ribbon Bond

Class of work---- ----------- Construction

Time of year------------------April

Conditions of traffic---------Hourly trains

Condition of track----------- Well up off ground,- ties, full spaced

Type of joint-----------------Continuous

Method of bond installation---Expanded into hole in rail web

Number of men in gang---------7

Rate of paynent of men--------8 hours per day at 14¢per hour

Men in charge---------------- One foreman

Salary of superintendence-----$60.00 per month.

Cost of bond----------------- 53¢ each in lots of 1000

Cost of bond installation-----11¢ to 14¢ average.

Remarks:-- The eight hour day means the time on the job, and does not include the time in going an d coming back. The joints were unspiked and held by but two bolts. The joints when bonded, were fully bolted and spiked. The low price was obtained by the ease of progress over the well set up track.

Type of bond installed --------Compressed Terminal Ribbon Bond

Class of Work-----------------Maintenance

Time of year------------------April

Conditions of traffic---------Regular trains hourly

Condition of track------------Fully ballasted roadway

Type of joint-----------------Continuous.

Method of bond installation---Expanded in hole in rail web.

Condition of joint------------Spiked and full bolted

Number of men in gang---------5

Rate of payment for men-------$1.50 per day

Men in charge-----------------One foreman

Salary of superintendence-----$50.00 per month

Cost of bond------------------53¢ each in lot of 1000

Cost of bond installation-----21¢ average

Remarks:-- Above track was originally installed with Flexible Mesh Soldered Bonds at the joints but after five months of operation, an average of four out of every five had fallen off, or had been knocked off. The average price arrived at, is only reached when the bonding gang has labored three hours or more.

Type of bond installed--------Flexible Mesh Soldered Bond

Class of Work-----------------Construction

Time of year------------------September

Condition of traffic----------Gravel trains at irregular intervals

Condition of track -----------Unballasted

Type of joint-----------------Continuous

Condition of joint------------Full bolted - spiked

Method of installation--------Soldered to ball of rail

Number of men in gang---------4

Rate of payment of men---- ---$1.50 for 10 hours per day

Men in charge-----------------One foreman

Salary for superintendence----$54.50

Cost of bond------------------27¢

Cost of bond installation-----52¢

Remarks:-- On the above work the joints needed no attention and the increase over a very low cost per bond installation

was due to to the cost of solder, gasoline, wear on the rail grinder, punches, acids, clamps, etc. This cost, however, does not include the costof soldering tools or of the grinding machine, which are necessary for soldered bond installation. The bonds were manufactured by the Flexible Mesh Bond Company of Ypsilanti, Michigan.

There are certain places in a track where bonds cannot be depended upon, such as at railroad crossings, at switched, frogs, and at the intersecting points where special work is employed, Fig. 4, except where such work work is welded. These places must be treated as open circuits portions of the track, and should be bridged over by jumpers, which should have a current carrying capacity equal to that of the outgoing overhead feeder at the points under discussion. There should be several connections with each rail, one for every 150 amperes to be carried. These connections can be made by cutting a flexible bond in two, fastening the end of the bond into permanent contact with the rail, and then soldering the jumper to the flexible portion of the bond. The jumper should be long enough to span the derailing switch, as these are generally not bonded.

No bond can hold for any length of time where the deflection of the joint under load is greater than three eighths of an inch. Such a deflection breaks the stranding and causes a rapid deterioration in the bonding, and a corresponding increase in the return drop.

Considered as a whole, the bonding problem is one which requires a great deal of attention. Generally

speaking , a 4/0 bond in the best possible condition has not sufficient capacity for a heavy traction line, especially so, if the road-bed is not up to the standard. Low joints will move under load, and cause the loosening of the best contact terminals. The result is a considerable loss in the return circuit, a trouble which is sometimes very difficult to detect and locate.

It is almost impossible for one to decide on a particular type of bond as the best, since all types have their special advantages and disadvantages. A soldered bond, even though it has no higher conductivity than the other types of equal capacity, is very easy, cheap and expedient to install, and may readily be inspected after application. It is true that at times some difficulty is experienced in securing men who can put on soldered bonds economically and permanently, but the same conditions exist in the installation of the pin expanded and compressed terminal types. In the former, laborers will grind their drills improperly, that is, with the point a little off center, so that the finished hole in the rail has an elliptical shape. This hole will then be open, possibly, on one side when the bond terminal is expanded into it. In the compressed terminal type, where a hand or screw compressor is used, the operator will not always strike the center of the lug to be compressed, and again, one man will exert one ton pressure against the terminal, and another man with the same apparatus and under the same conditions will exert ten tons pressure. Thse de-

fects cannot be discovered after the plates have been replaced and unless the work has been carried on by a trustworthy man the results are often very unreliable.

Another point against any type of bond which requires the opening of the joint for installation and maintenance especially where this work is under the pavement, is that in a great number of cases it is necessary to pull the spikes around the joint in order to remove the plates. As a rule, these spikes cannot be replaced in the same holes, and a place is therefore left where water can soak in and shorten the life of the tie by rot. Due to this single reason, it is oftimes economical and advisable to leave undisturbed, the plates on joints set in pavement, and jump the joint completely, tapping the bond into the rail outside of the ends of the plates.

The pin expanded terminal bond, nevertheless, embodies several good features, one of these being that it can be applied to special work, where it would be almost impossible to use a bond compressor or other type of bond.

Several roads in and around Indianapolis, Indiana, the interurban center of the Middle West, have installed soldered and electrically welded bonds with phenomenal success. From his limited experience, the writer is of the opinion that this latter type of bond is very efficient in conductivity and is hard to shear off, and furthermore is not over expensive to install, where a number of bonds is required.

The South Side Elevated Railway Company of Chicago, Illinois, have adopted the practice of installing one 500000

c.m. compressed terminal bond at each rail joint, after amalgamating both bond terminals and holes with a mercury amalgam. Their original installation of third rail, in 1897, was so treated, and has given very good results.

In conclusion, the selection of a suitable bond depends wholly upon the existing conditions, both of installation and operation. A question always asked, is, what is the best bond? The answer is, the best installing workman makes the best bond. The care exercised in applying bonds makes them effective connections or so much junk. Certain points are essential; with the best of care , bonds installed without heat should not be installed in wet or damp weather, as any moisture will start corrosion of the contacts.

The mechanical joints as electrical connections stand in the following order: the electric weld gives the most uniform resistance, running about the same as the rail, depending upon the size of the splice bar used: the cast weld varies as the temperature of the metal, which determines the degreeof amalgamation, the joints poured in succession gradually increase in resistance as the temperature of the metal falls. In one heat, with more than one pouring in, a joint incr ases in resistance. Thermit joints appear very well, but enough have not as yet been tested to determine their exact standing in comparison with other joints. However, they are not superior to electrically welded joints In regard to the mechanically placed bond , it can only be

said, generally, that when these bonds are installed by the line department thay give better results than when installed by the track department, and when one man has charge of and is responsible for all the bonding, its installtion and testing, far better results are attained than where it is done in a hap hazard fashion by the track gang.

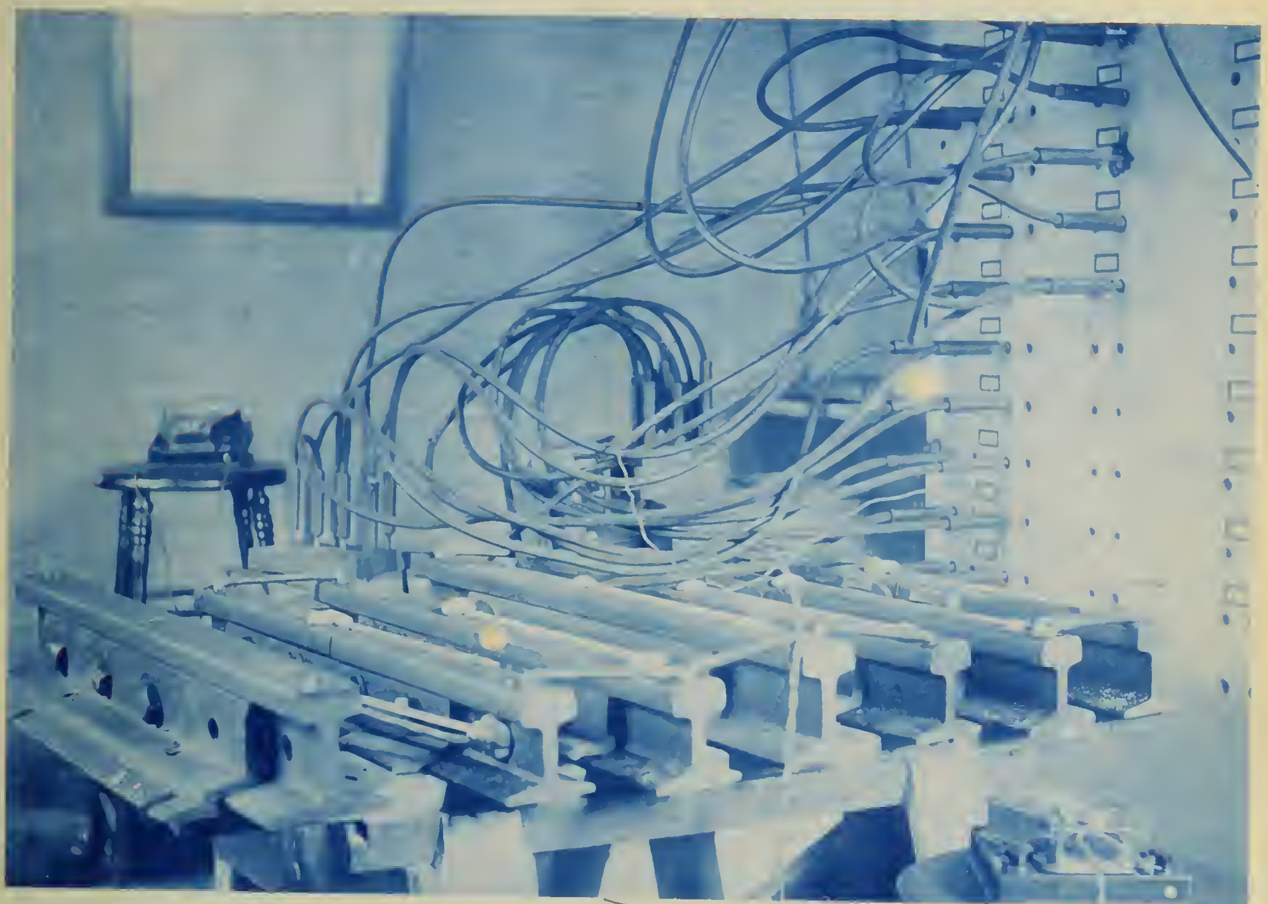


Fig. 1.


APPLICATION OF PROTECTED RAIL BONDS
ON THE LONG ISLAND RAILROAD

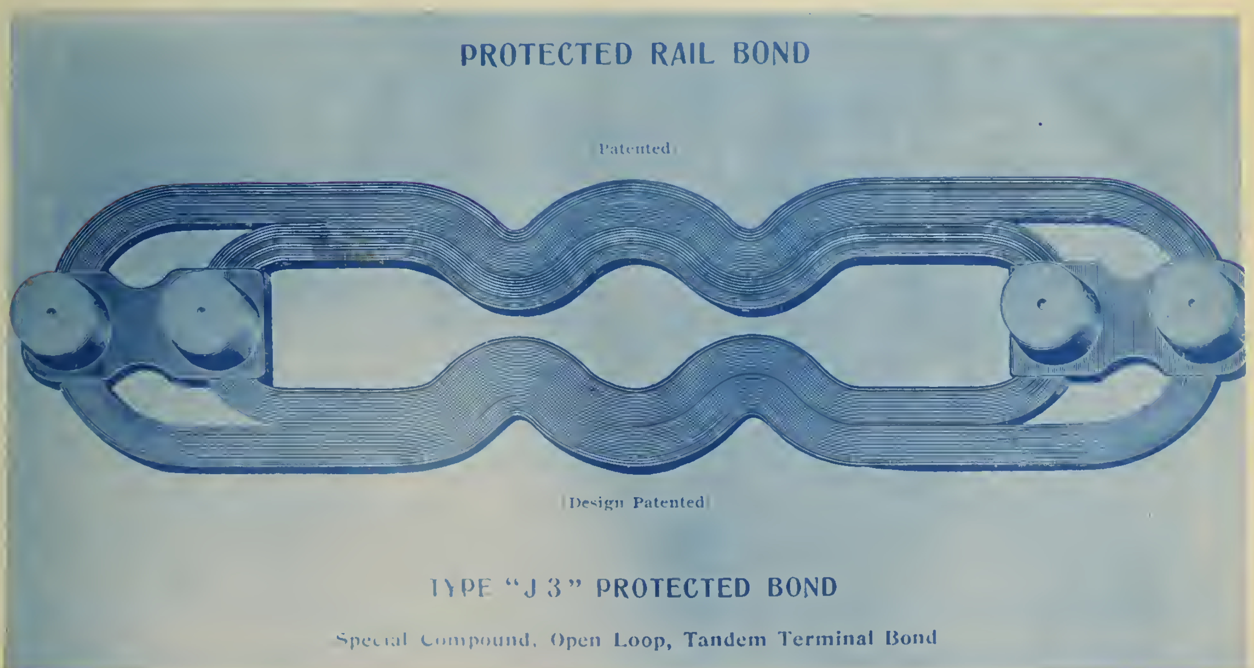
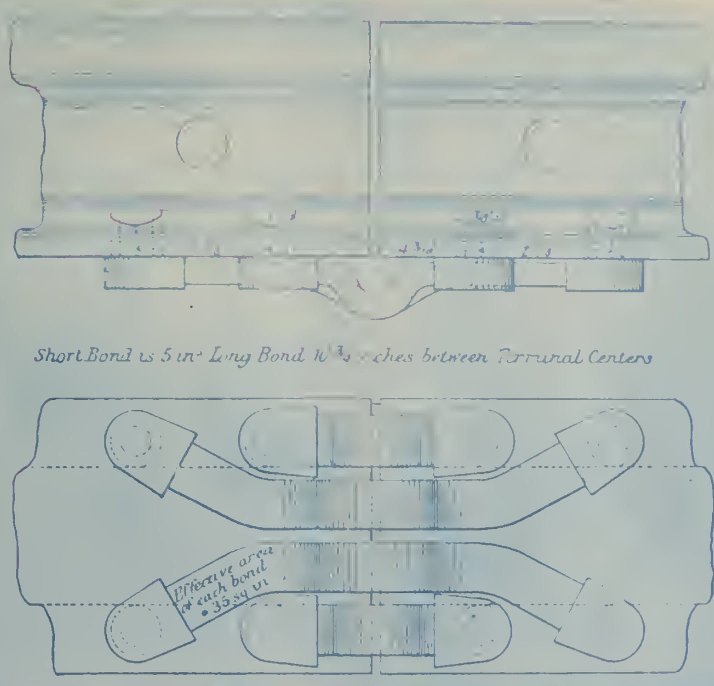

PROTECTED RAIL BOND
(Patented)
(Design Patented)
TYPE "J 3" PROTECTED BOND
Special Compound, Open Loop, Tandem Terminal Bond

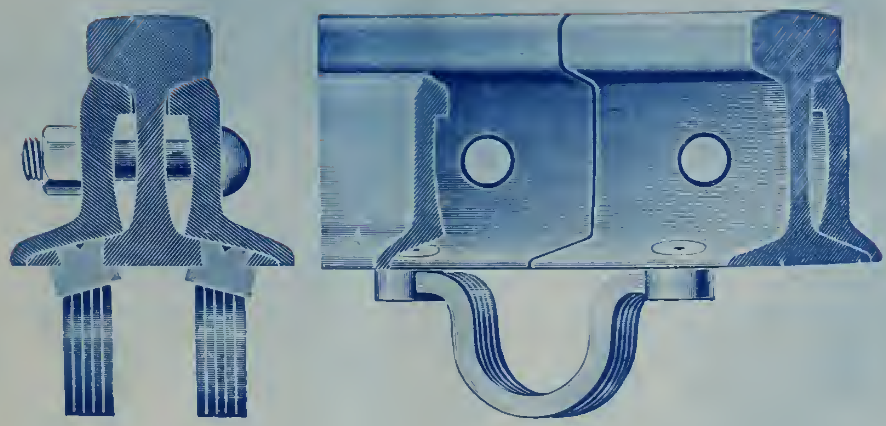
Fig. 2.

STEEL CORE TERMINAL SHOWING DIRECTIONS OF EXPANSION OF CORE



g. 241. PROTECTED TYPE OF BONDS ON LONDON UNDERGROUND ELECTRIC RY.

Fig. 3.



Showing two Type "L 3" Protected Bonds applied to base of "T" [illegible] with our Hydraulic Punch and Compressor. This is the standard bond-[illegible] adopted for the contact rail by the leading "Third Rail" roads

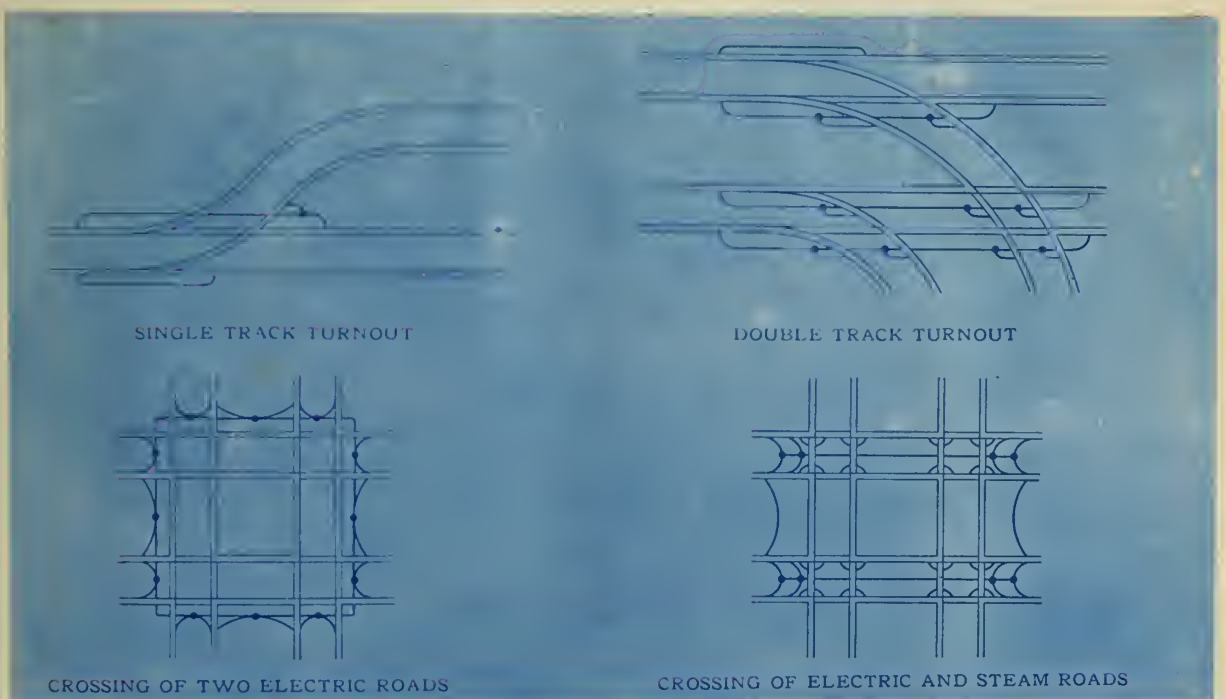
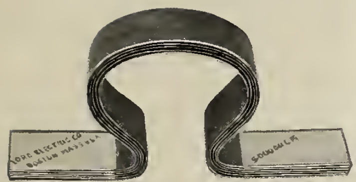
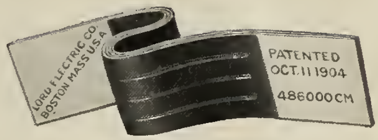


Fig. 4.

SOME STANDARD TYPES



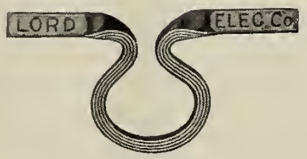
TYPE "A" BOND



TYPE "B" BOND

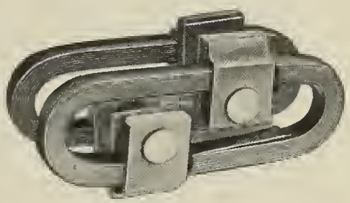
TYPE "C" BOND, FORM 1

TYPE "C" BOND, FORM 2



TYPE "C" BOND, FORM 3

TYPE "D" BOND



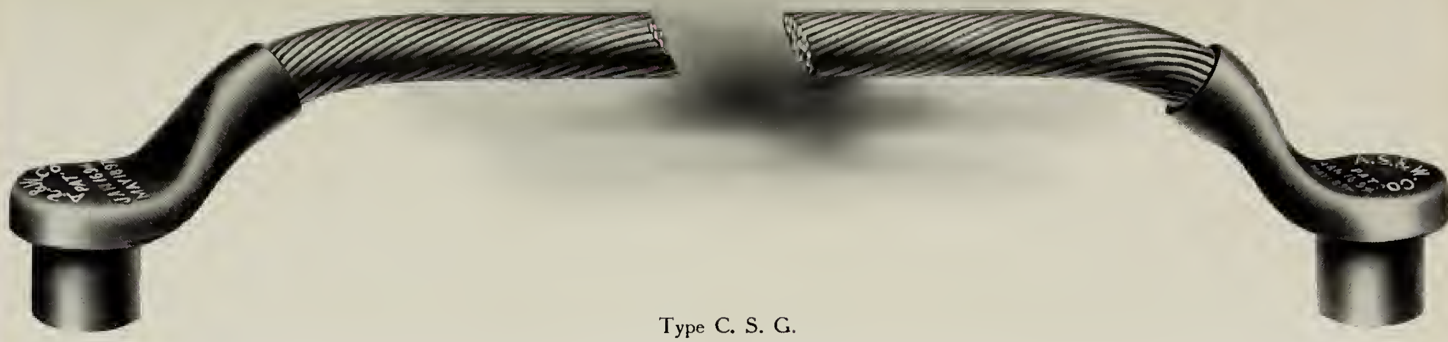
TYPE "E" BOND

TYPE "F" BOND

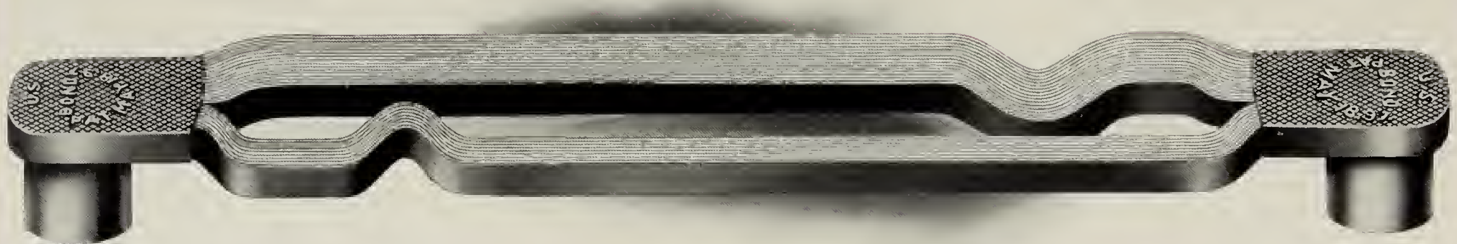
TYPE "G" BOND, FORM 1

TYPE "G" BOND, FORM 2

Fig. 5.



Type C. S. G.
CROWN RAIL BOND

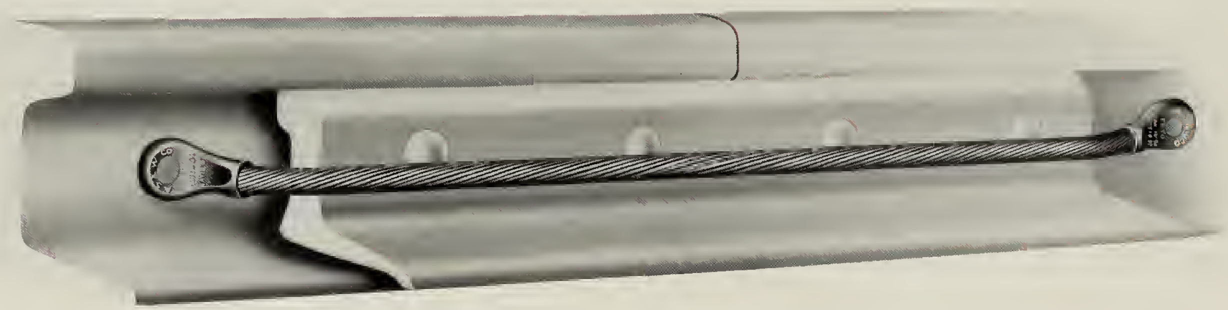


Type U. S. 5
UNITED STATES RAIL BOND

Fig. 6.

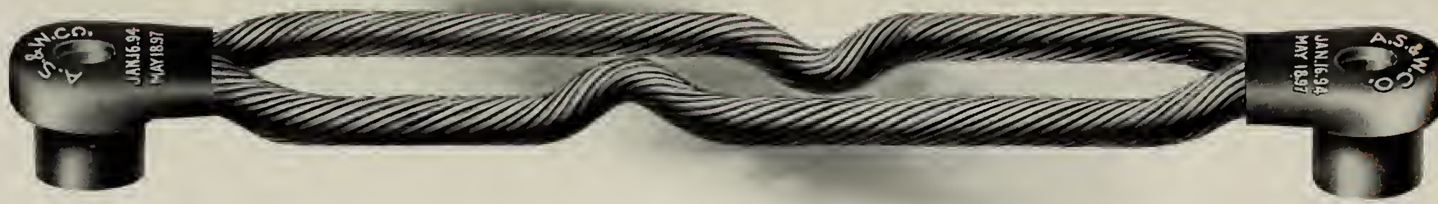
Fig. 7.

Type C. P. G.
CROWN RAIL BOND

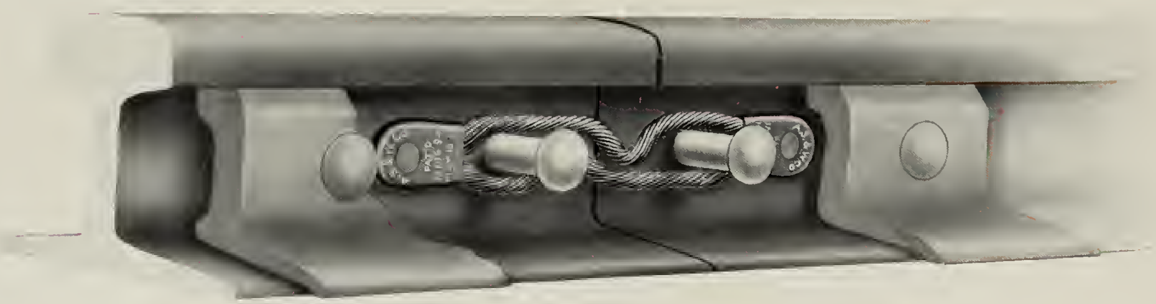


Showing application of Type C. P. G. Crown Rail Bonds

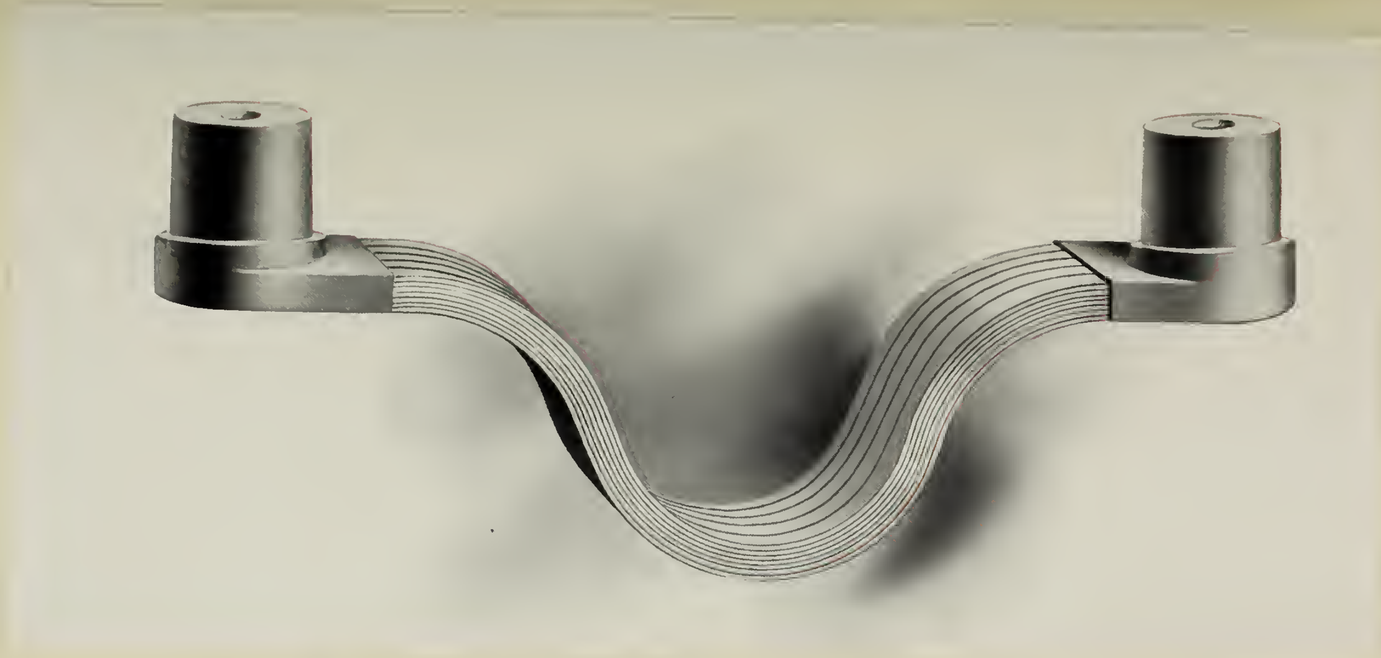
Fig. 8.

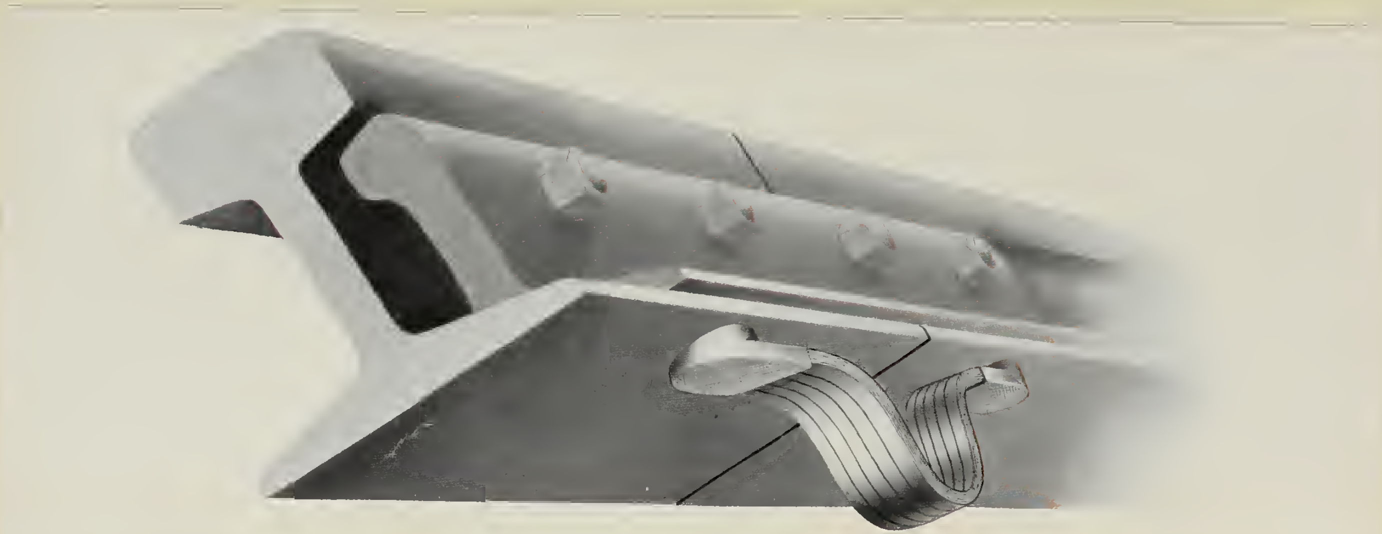


Type C. P. 2
CROWN RAIL BOND



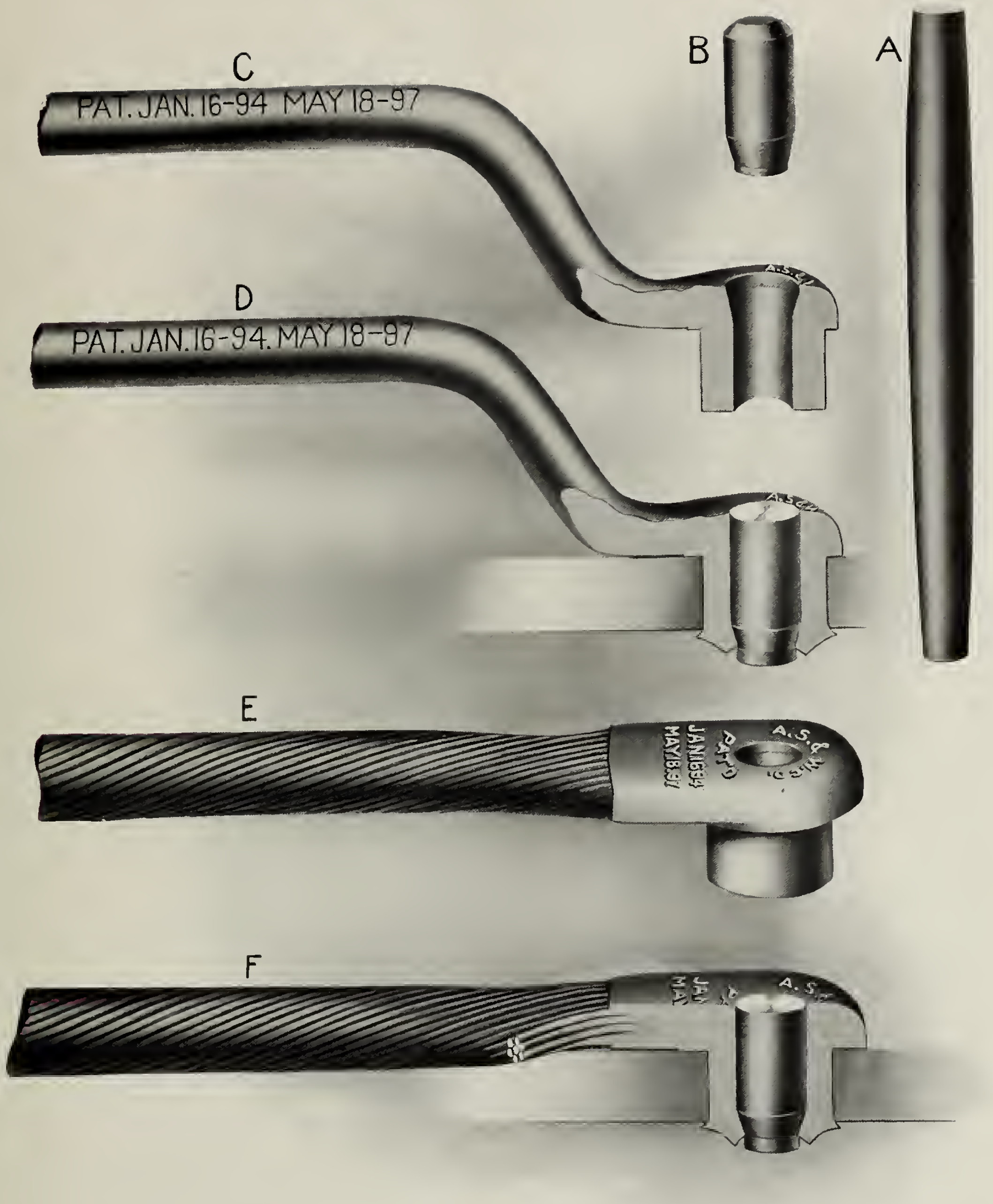
Showing application of Type C. P. 2 Rail Bonds





Showing application of U. S. B. United States Rail Bond

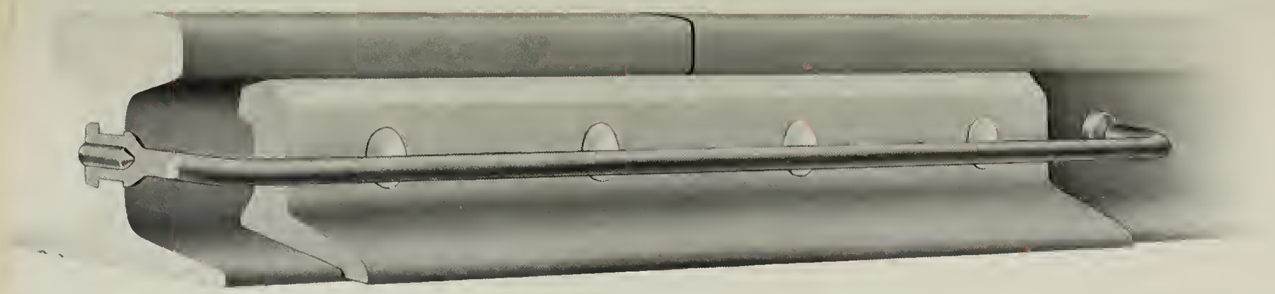
Fig. 9.



TUBULAR TERMINALS

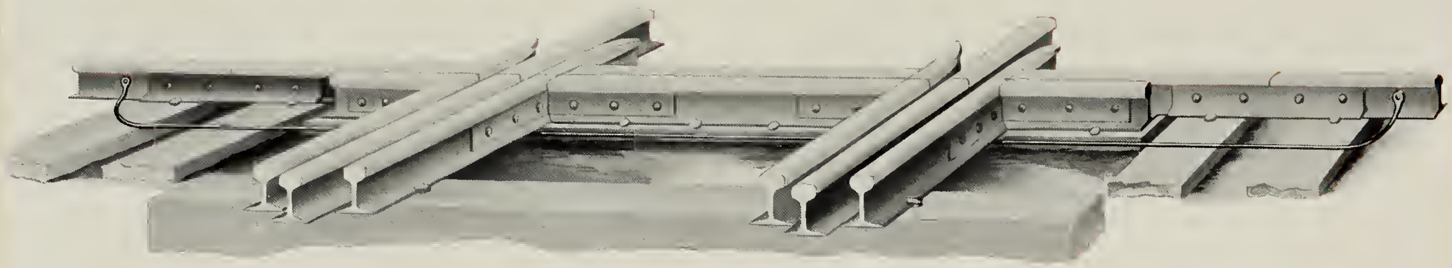
Fig. 10.

Fig. 11.



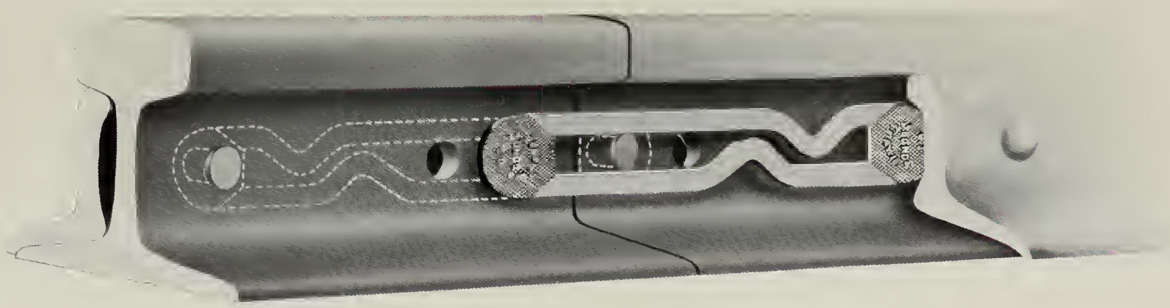
Showing a Type C. P. A. Crown Rail Bond applied

25

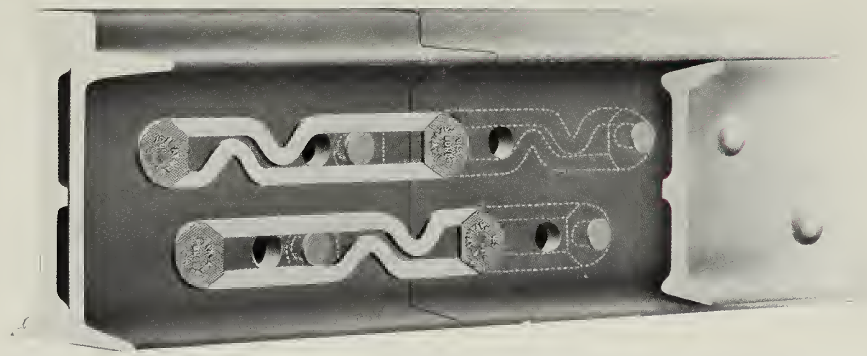


Showing a Type C. P. S. Crown Rail Bond spanning special track work

24



Showing application of Type U. S. 4 United States Rail Bonds on T rails



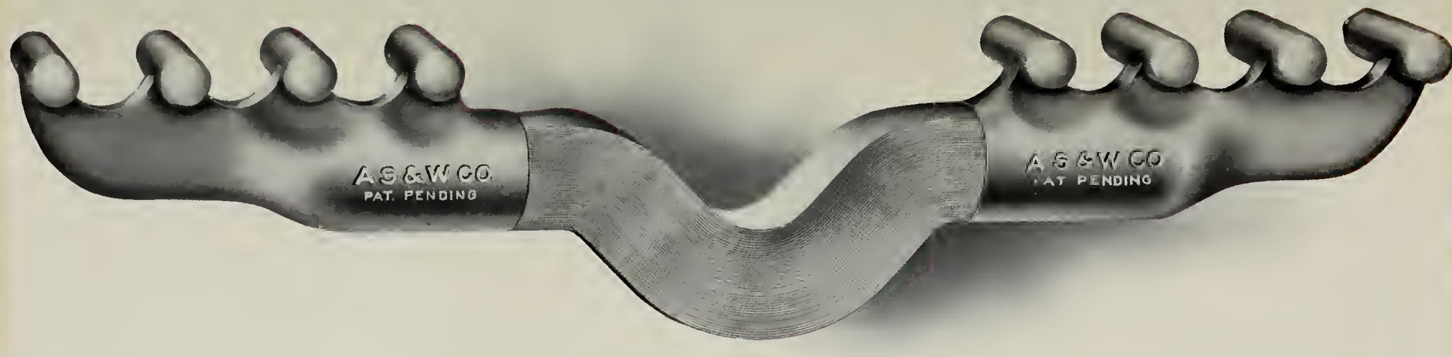
Showing application of Type U. S. 4 United States Rail Bonds on girder rails

Fig. 12.

Type C. P. C.
CROWN RAIL BOND

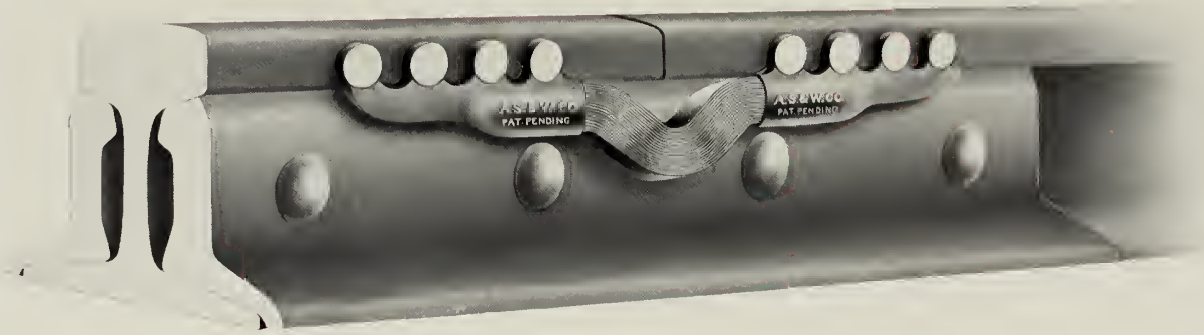
Type C. P. T.
CROWN RAIL BOND

Fig. 13.



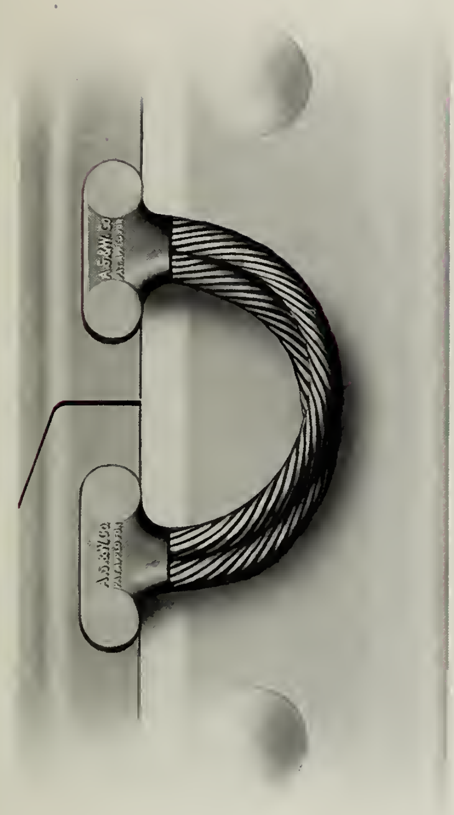
QUADRUPLE TERMINAL RAIL BOND

[Patented Oct. 30, '06]



Quadruple Terminal Rail Bond shown installed

Fig. 14.

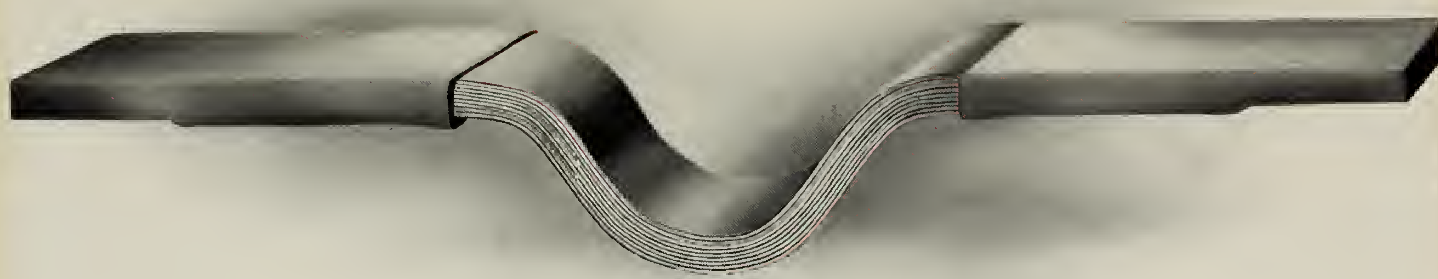


Showing Twin Terminal Bond applied.

[Patented Oct. 30, '06]

TWIN TERMINAL BOND

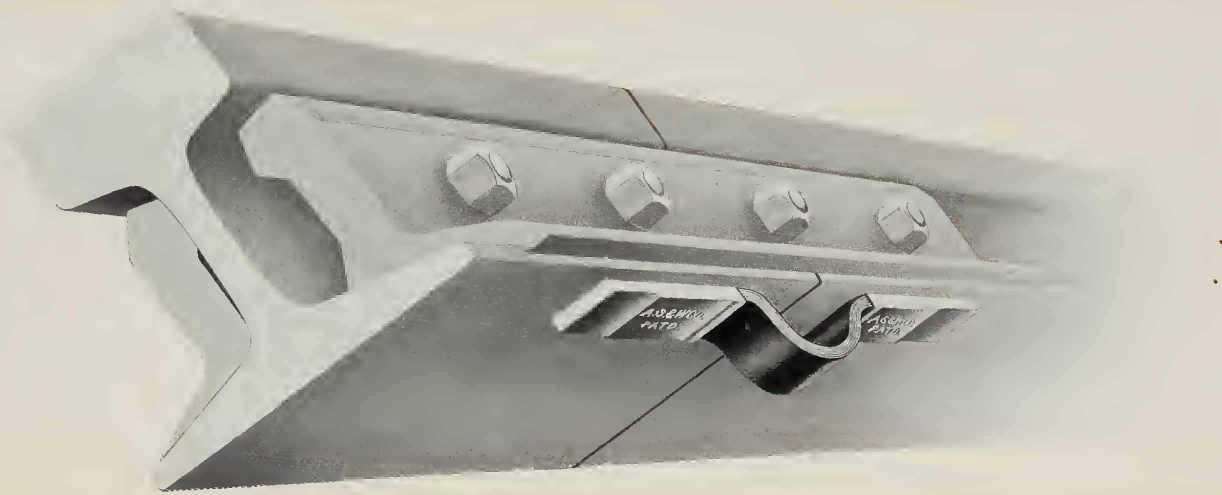
Fig. 15.



[Patented May 18, '97]

Type S. B.

FORM 2 SOLDERED BOND



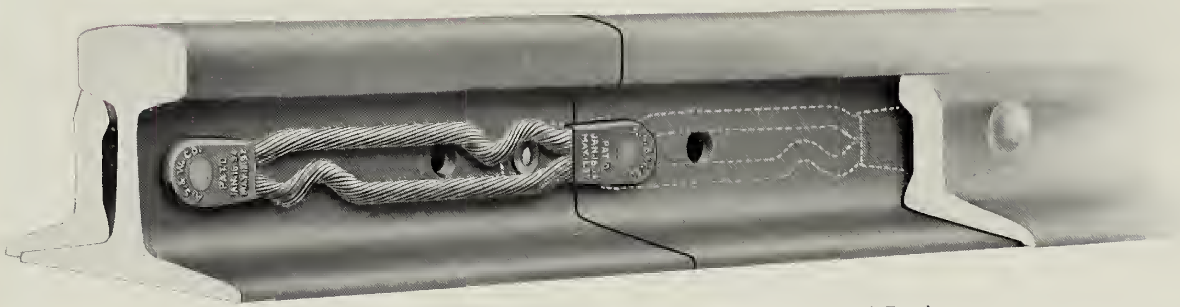
Showing application of Type S. B. Form 2 Soldered Bond

Fig. 16.

Fig. 17.

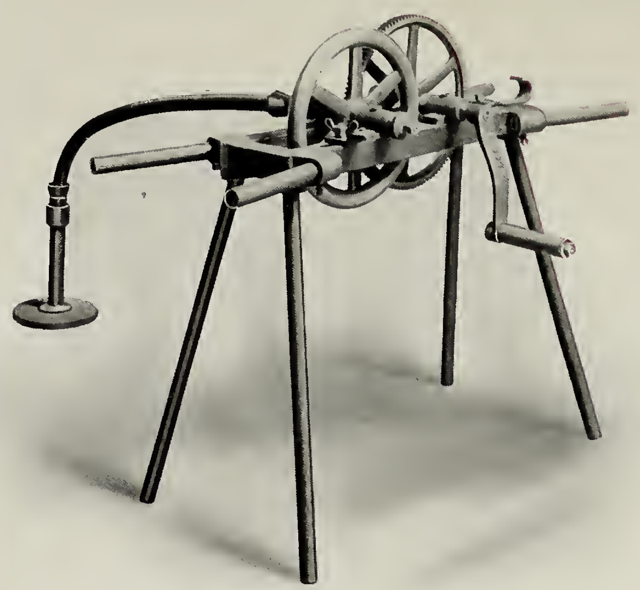
Gasoline Motor Grinder.—For large installations, when electric power is not available, this gasoline motor outfit is an economical expedient for grinding rail surfaces. An efficient, high-speed bicycle motor is mounted on a small platform or car and connected to a countershaft, having a friction clutch which can be used to start or stop the flexible shaft. The whole outfit is light and easily handled.

GASOLINE MOTOR GRINDER
No. 82

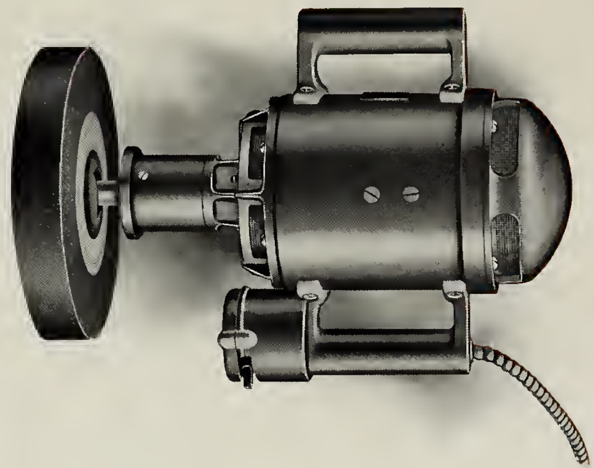


Showing application of Type C. P. 6 Crown Rail Bonds

GRINDING MACHINES FOR SOLDERED RAIL BONDS



HAND-POWER GRINDER
No. 80



PORTABLE ELECTRIC GRINDER
No. 81

Hand-Power Grinding Machine.—The frame of the hand-power grinding machine is made of cast steel. All wearing parts are machined accurately to size. The shaft is our special design, made of the highest grade of tempered spring steel and is very flexible. This machine, though light and easily handled, will endure very rough usage.

Portable Electric Grinder.—We illustrate here our very convenient outfit for grinding rail surfaces when electric power is available. A small five hundred volt motor with rheostat and switch attached to the handle has the emery wheel mounted directly on the armature shaft, as shown. The circuit is thoroughly insulated from the motor frame. Total weight, 28 pounds; speed 2500 rev. per minute.

Fig. 18.

HYDRAULIC PUNCHES AND COMPRESSORS

Two Hydraulic Compressors, mounted on carriage, showing man operating one compressor

Fig. 19.

FOR REBONDING GIRDER RAILS IN PAVED STREETS WITHOUT TEARING UP THE STREET, REMOVING THE ANGLE PLATE OR INTERRUPTING TRAFFIC.

INSTALLING THE SEMI-PLASTIC PLUG RAIL BOND WITH ELECTRIC DRILL AND MAGNETIC CLAMP.

THE

PLASTIC PLUG BOND

FOR REBONDING

TEE RAILS

WITHOUT REMOVING

ANGLE PLATES.

Made of the New Process Plastic Alloy

AND WILL STAY PLASTIC.

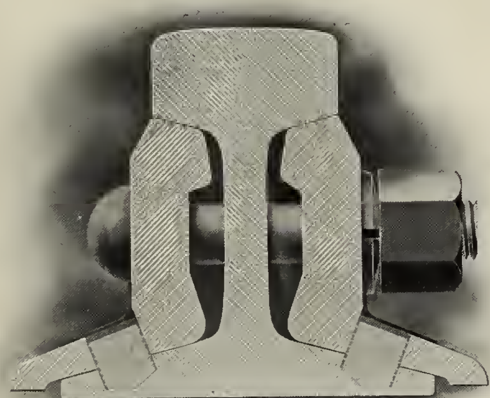


FIG. 3.

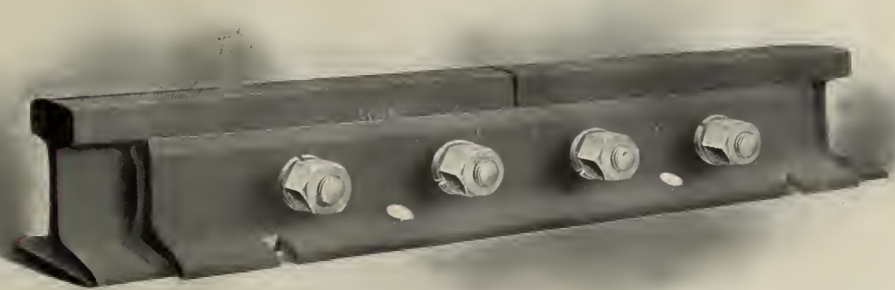


Fig. 20.

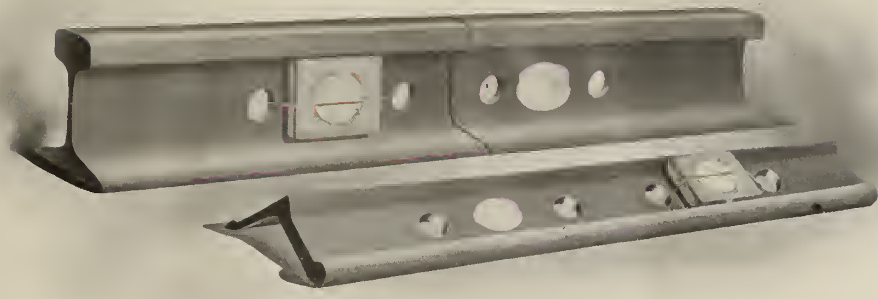


FIGURE 9.—PLASTIC RAIL BOND READY FOR APPLICATION.

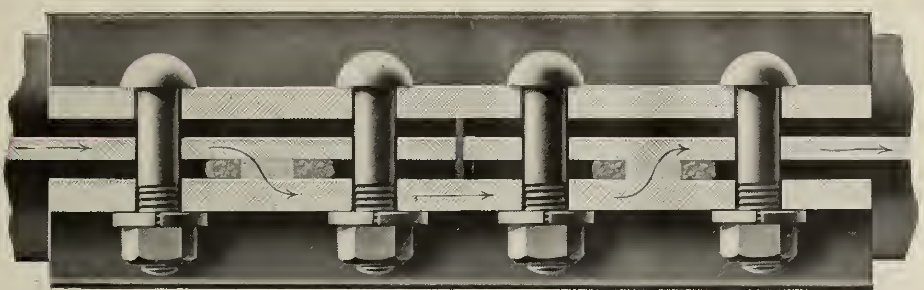


FIGURE 10.—HORIZONTAL SECTION.

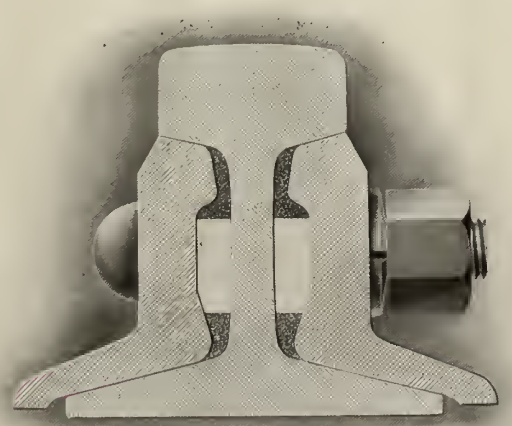
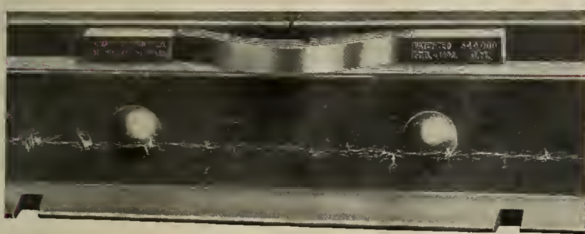


FIGURE 11.—END SECTION.

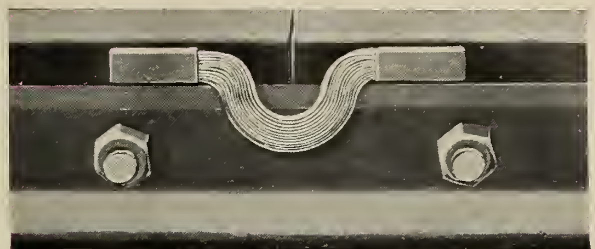
Fig. 21.

Type "CC" Bond. Attached to Web of Rail.

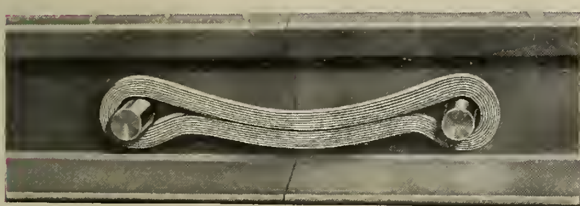
Type "BB." Installed.



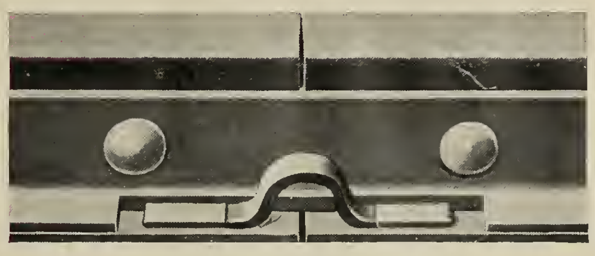
Type "A" Special Applied.



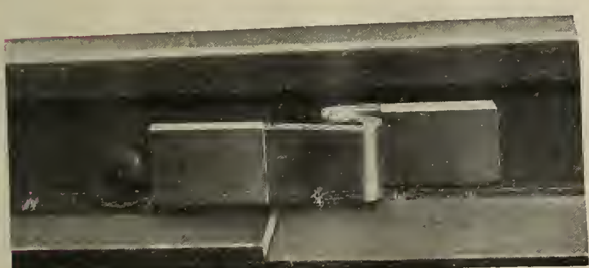
Type "C" Bond. Attached to Ball of Rail.



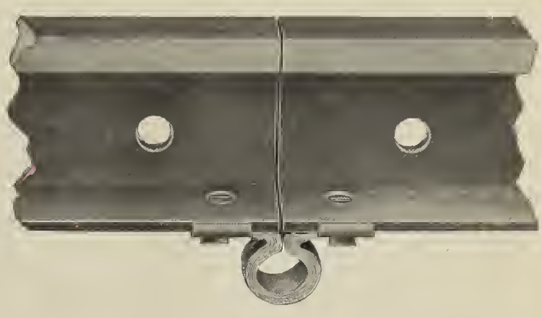
Type "S" Bond Applied.



Type "A," Flange.



Type "W" Bond Applied.



PAT. MARCH 1, 1904 -- AUGUST 23, 1904
TYPE "A" BOND ATTACHED TO BASE OF RAIL BY SOLDERING AND BOLTING

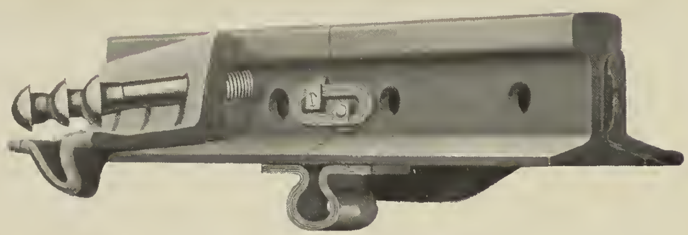
Fig. 22.

Fig. 23.

TYPE "B" BOND ATTACHED TO WEB OF RAIL AND JOINT PLATE

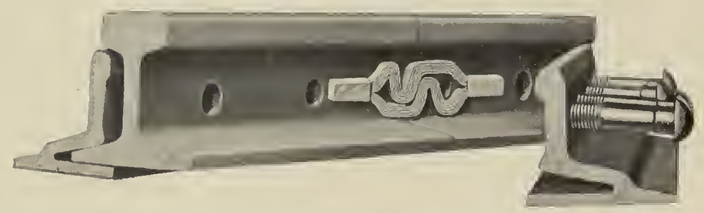
TYPE "D" BOND ATTACHED TO WEB OF 70 POUND RAIL UNDER A WEBER JOINT

TYPE "G" BOND, FORM 1 ATTACHED TO WEB OF 70 POUND RAIL UNDER A WEBER JOINT



TYPE "E" BOND ATTACHED TO WEB OF 80 POUND RAIL UNDER A BONZANO JOINT

TYPE "A" BOND APPLIED TO BASE OF SAME RAIL



TYPE "G" BOND, FORM 2 ATTACHED TO WEB OF 70 POUND RAIL UNDER A CONTINUOUS JOINT